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Prairie Restoration and Species Diversity: A Comparison of Propagation Success Between Seeded and Planted Forbs

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PRAIRIE RESTORATION AND SPECIES DIVERSITY: A COMPARISON OF PROPAGATION SUCCESS BETWEEN SEEDED AND PLANTED FORBS

BY

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ABSTRACT

Prairie ecosystems used to dominate Illinois' landscapes, providing some of the most organically rich soils in the world, supplying homes to hundreds of native species, and conserving soil and water. The deep rooted forbs prevent water runoff and soil erosion. Economically the prairies have provided medicines, commercial forbs, and aesthetically pleasing landscapes for humans. Society is dependent on the rich soils these prairies have provided for agriculture and for prevention of erosion and water runoff. With less than one tenth of one percent of Illinois prairies still remaining, successful prairie restoration is of the utmost importance. In order to achieve the highest quality prairie that consists of the most diverse communities, researchers and prairie managers need to continue to revise best management practices. Currently prairie managers introduce grasses and forbs by seeding disturbed areas and then manage the prairie year to year with a mixture of pesticides and prairie fires to control weed growth. The drawback to this method is that it may take decades to achieve maximum species diversity for each site, leaving community residents frustrated at the slow growth of colorful forbs. This study aimed to improve the growth rate of forb species in restored prairies by analyzing best practices on agricultural fields in Will County, Illinois. In this study, three management approaches were employed to examine the relationships between prairie restoration process and species diversity. The three management approaches were seeding with grasses and forbs (SGF), seeding with grasses and hand planting forbs (SGH), and neither seeding nor hand planting grasses or forbs (NSG). The results showed that in the NSG treatment (also the control treatment) relatively few plants dominate the community. Most of these species, including giant foxtail, dandelion and

Canadian thistle, had Coefficient of Conservatism (C) values of 2 and below. The SGH treatment and the SGF treatment had a better representation of species, including giant foxtail, black eyed susan, purple prairie clover, new England aster and wild bergamot. C values averaged approximately 5 in these treatments. Floristic Quality Index (FQI) values were below 20 for all three treatments but the SGH treatment was the highest with an FQI value of 8.56 compared to 8.24 for the SGF treatment and 6.14 for the NSG treatment. A statistically significant difference exists between sampling years 2009 and 2010 ($F_{1,27}=65.54$, $p<0.05$), between treatments ($F_{2,27}=168.85$, $p<0.05$) and between the interaction of treatment and year ($F_{2,27}=4.22$, $p<0.05$). The results showed that the hand SGH treatments appear to have higher species diversity but have a significantly larger cost than the SGF treatments. This study may be used in the future management of local prairies, especially those used as open land projects in new subdivisions. Though the SGH treatment has higher species diversity it comes at a cost and the ultimate decision whether to put forth this additional expense will be based upon the community's support. The community's desire for aesthetics (seeing more forbs in the first few years of prairie growth) may outweigh their concern for cost.

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INTRODUCTION

The prairie community is a complex network of grasses and forbs and their interactions with prairie fauna. Prairie soils are some of the most organically rich soils and contain mutualisms between forbs and bacteria and forbs and fungi. Its success depended on grazing by prairie herbivores and periodic natural fires that suppressed the growth of trees (Fuhlendorf & Engle 2004; Copeland et al 2002; Kettle et al 2000).

The prairie biome used to cover a large portion of the Midwest but now it is difficult to find any remnant prairies. The prairies have been plowed for agriculture, used as commercial and residential sites, and/or suppression of wildfires led prairies to become converted into forest ecosystems. Though Illinois was a vast landscape of prairie and oak maple forest, only one hundredth of one percent of Illinois prairie still remains. Due to this great loss of the prairie, Illinois has experienced a decline in native plant and animal species diversity and an increase in number of invasive species. The remnant prairies are now so fragmented it is easy for them to be encroached upon by invasive weedy species and they can no longer support the large numbers of plants and animals they once did (Page 1997; Whitney 1994; Saunders 1991; Anderson 1990; Kuchler 1974). In order to insure that our plant communities remain diverse, which in turn will benefit both flora and fauna in the prairie community, Illinois must make an active effort to increase the number of high quality prairies.

Based on their origin, prairie communities can be classified in two categories: prairie remnants and prairie reconstructions (Pywell et al. 2003; Smith et al 2003; Polley et al 2005). Prairie remnants are parcels of land that have been used primarily for grazing or left intact. These sites have limited soil degradation and are more likely to have high species richness and vegetation integrity. Prairie reconstructions are typically agricultural fields converted back into natural prairies. Their soils tend to be degraded and their native species have increased competition with adventive species, leading to difficulty obtaining high species richness and habitat quality. These latter prairies typically require larger workforces, more money, and more time to restore back to pre-disturbance condition prairies.

When restoring agricultural fields back to a prairie community it is often unrealistic to expect species diversity and ecosystem function approaching a remnant prairie. Years of farming, degeneration of soils, nutrient leaching, and other disturbance can prevent sites from ever reaching pre-settlement conditions. However, with an understanding of the site's soil composition, disturbance history, and community resources the prairie community can reach its maximum potential.

There are two theories of thought on prairie management. Succession theory describes pioneer species--such as grey-headed coneflower (*Ratibida pinnata*), black-eyed susan (*Rudbeckia hirta*), and wild bergamot (*Monarda fistulosa*)--being replaced by long lived species such as legumes and compass plant (*Silphium laciniatum*). Pre-settlement condition refers to climax communities that contain high species diversity of long-lived species, rather than shorter-lived weedy species. Equally important are the soils of the prairie that contain energy rich compounds, diverse microbes, and mutualistic relationships, such as mycorrhizal fungi and rhizobial-root nodules (Packard & Mutel 1997). Therefore, knowledge of soil and herbicide history has vast impacts on what types of grasses and forbs may grow.

The alternative assembly theory encourages viewing prairie restoration not as having one endpoint or climax community, but as having many potential end points as a result of human disturbance that may have created “restoration thresholds” that limit the achievable prairie community. When reconstructing prairies we should take into account disturbance history and site limitations. It appears to some restoration ecologists that obtaining the original diversity of vegetation could take 50 – 100 years or more, if it is even possible (Kindscher & Tieszen 1998). Thus, the goal of restoration should not be an unrealistic one of pre-settlement condition but one of maximizing the full potential of the site (Temperton et al 2004).

Implementation and management of prairie restoration of former cropland sites has changed over the past 50 years. One of the oldest known prairie restorations in the U.S. is found at the University of Wisconsin Arboretum, which began in 1935. This restoration involved seedling planting, seed casting and transplanting of prairie sod, with few forbs (Cottam & Wilson 1966). Rockefeller tract at the University of Kansas involved disking and sowing commercial native grass mixtures with no forbs planted in the late 1950’s (Fitch & Hall 1978). Fermi National Accelerator Laboratory’s prairie restoration involved dispersal of seeds and no transplantation (Betz 1986). The USDA’s Conservation Reserve Program (CRP) has converted 14.8 million hectares of cropland to native prairie. The CRP has been criticized for their focus on the use of only four to five native grassland species and not always seeding forbs, as these practices impede the land’s restoration to a highly diverse prairie (Kindscher & Tieszen 1998**).** Recent restorationists recommend at minimum broadcasting native grass seed mixtures, preferably collected from local prairie remnants, or alternatively purchased commercially. In the first or second year forbs should be seeded or planted. Though time frames surrounding prairie burns vary, most research seems to suggest burning on a rotation between 1-4 years (Fitch & Hall 1978; Sluis 2002). Prairies are burned to encourage grass and forb growth and discourage woody species (Packard & Mutel, 1997; Collins & Wallace, 1990).

In order to improve prairie management and conservation procedures, it is imperative to study the factors that affect species diversity and community integrity. Both succession and assembly theory need to be considered when managing. A history of the site, soil data, and herbicide history need to be recorded and though we strive for pre-settlement conditions, realistic goals need to be set considering the limitations of the site. Currently, high quality prairies are defined as those with high species richness, including rare and common species, and representative of pre-settlement conditions. There is no conclusive opinion on best practices for evaluating prairie quality but current literature supports using two indices: the Floristic Quality Index (FQI) which ranks prairie health and the Mean Coefficient of Conservatism (Mean C), which gives values to a range of invasive to rare species from 0 to 10, to measure vegetation integrity (Taft et al 2006; Bowles & Jones 2006). The coefficients are supported by the ecological trends that plant species vary in their tolerance to disturbance and their ability to live in different quality habitats (Taft et al 2006; Bowles & Jones 2006). Species ranked with a C value of 0-1 are taxa that have adapted to severe disturbance, C values of 2-3 signify taxa found in disturbed but less degraded prairies, C values of 4-6 include matrix species that often dominate the prairie, C values of 7-8 are taxa that are usually in natural areas but may be found in some degraded areas, and the rarest species that persist in only high quality prairies have C values of 9-10. Success of the reconstruction or quality of the site will be compared by collecting species composition and abundance data and analyzing those data with FQI analysis and its component Mean C. Taft et al. (1997) recommends using the Floristic Quality Assessment (FQA) that integrates the FQI and Mean C with other important vegetative measurements.

One of the largest factors limiting prairie reconstructions is financial constraint. Restoring a bare agricultural field requires large amounts of native prairie seed and/or expensive mature forbs. Typically, the agricultural fields are seeded with a mixture of grasses and forbs while some sites have also been planted with native forbs to encourage certain species to propagate.

Reconstruction managers may be reluctant to hand plant forbs because of the increased expense of buying forbs compared to buying seed. In addition, there is also an increased labor cost to hand planting. However, if planting can insure a higher likelihood that the site reaches its full potential and maximum community structure the initial investment would be worth the cost. It may be that the initial investment of buying species for transplanting will cost less, in the long run, than years of buying seeds and paying labor cost to weed the site. In addition, one does not want to exclude the intrinsic value that a high quality prairie will have for all those associated with it. Packard and Mutel (1997) claim that hand-planted and hand-weeded prairies are some of the most spectacular prairies to behold. If large fields are hand-planted but not hand-weeded will there be a significant enough difference in prairie quality to justify the cost? In this study, I will ascertain whether or not planting significantly increases prairie quality and if this increase in prairie quality is work the monetary investment.

The overall objective of the project was to test best practices on agricultural fields in Will County. In this study, three management approaches were employed to examine the relationships between prairie restoration process and species diversity. The three management approaches were seeding with grasses and forbs (SGF), seeding with grasses and hand planting forbs (SGH), and neither seeding nor hand planting grasses or forbs (NSG).

The specific objectives of the study were: (1) to determine the composition and structure of species in the restored prairies using the three approaches; (2) to examine the quality of the prairies restored by three methods using the parameters FQI, Mean C, and other derived parameters (species richness, relative importance, percent of taxa that are native and adventive, number of rare species, and guild diversity); and (3) to analyze the cost-benefits from the three treatments.

The first objective of the study was to compare three treatments on an agricultural field: areas where grasses and forbs are seeded; areas where grasses/forbs are seeded and mature forbs are planted, and natural areas where no grasses or forbs are seeded or planted (control). The null hypothesis predicted there would no significant difference in number of species between the three treatments.

The second objective was to measure prairie quality using three methods. There is no conclusive opinion on best practices for evaluating prairie quality, but current literature supports using the FQI and its Mean C that ranks invasive to rare on a 0 to 10 scale, to measure vegetative integrity. The additional measurements include species richness, relative importance, number of taxa that are native and adventive, and guild diversity. Guilds may be delineated based on wetland affinity, conservatism rank, or physiognomic class. The null hypothesis states that FQI, Mean C, and additional parameters analysis will show no significant difference between the three treatments.

The third objective of the study was to determine if there is a benefit vs. cost advantage associated with any of the three treatments. Will County encourages that new residential development on unincorporated land set aside 50% of the property as open land. Open land is property that can no longer be built upon; it is managed by a homeowners association, park district, forest preserve, or land resource management group. Though this open land can range from farmed land to hiking trails, many subdivisions are choosing to restore the land to native prairie. Light House Point subdivision in Frankfort, Illinois is a good example of a successful prairie managed by a land management group. This community incorporated a bike path and ponds with natural vegetation managed by Frankfort Square Park District, Village of Frankfort, and The Management Groups. By sharing the responsibility the success of the conservation effort increases over time due to the number of individuals involved with project. However, some prairies are managed by homeowners associations and public organizations that tend to lack expertise, time or funding for long-term projects. Tall Grass Preserve Subdivision in Frankfort, Illinois is an example where the prairie was planted but soon fell into a low quality prairie with many invasive species and low diversity. If hand planting forbs was significantly more successful in increasing initial prairie quality, it would be worth the initial expense for these communities to hand plant forbs. It may also reduce their future management investment. The null hypothesis was there will be no cost-benefit differences between the three treatments.

MATERIALS AND METHODS:

Site Description

The research site is located on Elevator Road, 1 block south of Route 52, in Manhattan, Illinois, Will County. Manhattan, Illinois has a temperature range from 29 to -10 °C. The mean annual temperature is 9.4 °C and mean annual precipitation is 91.8 cm/year. The site is part of a 4.05 ha piece of farmland that has been agriculture land for at least 20 years. The site has been planted to corn and soybeans on a rotating basis, and the main pesticides used were Roundup (glyphosate) and 2, 4-D. The total area used in the study was a 30 m x 100 m area. The 100 m eastern edge of the study site is adjacent to Elevator Road and the other 3 sides are adjacent to agriculture fields. Though this site is adjacent to the road and small in size, these characteristics are also true of prairies in subdivisions. The site features Elliot silt loam, Ashaum silty clay loam, and Peotone silty clay loam soil. The area is surrounded by open farmland and therefore is free of shading from trees.

Experimental Design

The study was a repeated measures design. Three treatments were implemented: Treatment 1 was SGH, treatment 2 was SGF, and treatment 3 was NSG (as a control). Treatment 1 was an artificial prairie restoration method using seeded grasses/forbs and planted forbs. This treatment had the potential to create high quality prairie in a reduced time period. It may be suitable for prairie restorations in relatively small areas and in new subdivisions, but it may be more expensive in terms of seeds, human power and tools. Treatment 2 was an artificial prairie restoration method using seeded grass and forbs. This approach has been recognized as efficient and economical, especially for large restoration areas. Time periods needed for plant establishment may be extended, however, and prairie quality may be diminished. Treatment 3 was a control treatment without seeded and planted grasses and forbs, or a natural prairie restoration method. The benefits include low cost for seeds, human power and tools, and is often practiced in remote areas. The disadvantage of this approach is lower species diversity and increased time to see significant prairie quality.

Within the 30 m x 100 m study site 30, 3 m x 3 m quadrats were marked, with adjacent quadrats separated by a 5 m buffer area. The three treatments were systematically assigned to individual quadrats, for 10 replicates of each treatment. Quadrats were seeded and hand planted during 2009, and data were collected during June through September 2009 and 2010.

Field Methods

Hand planted species and native seed mix were obtained from Prairie Moon Nursery during May 2009, and quadrats were seeded and forbs planted during 2009. Thirty-nine plants were planted by hand 0.3 m apart in each SGH quadrat. Hand planted species were black-eyed susan (*Rudbeckia hirta*), purple prairie clover (*Petalostemum purpureum*), prairie blazing star (*Liatris pycnostachya*), purple coneflower (*Echinacea purpurea*), pale purple coneflower (*Echinacea pallida*) and New England aster (*Aster novae-angliae*). Seven of each of these species were planted in each SGH quadrat; however, only four New England asters were planted per quadrat.

The seed mix used included 30 species, with number of seeds in a 60:40 ratio of forbs to grasses. The majority of species in the seed mix were perennials. The seeds were mixed with perlite before broadcasting. Quadrats were seeded only during 2009, because one initial seeding is consistent with restoration methods employed by the local management groups who are hired to develop the subdivision conservation developments. The buffer areas around quadrats were mowed once every two weeks during the two summers of the study.

During June through September of 2009 and 2010, number of stems and percent coverage were recorded every two weeks for each species in each quadrat. At each quadrat, a ¼ m^2 quadrat was thrown blindly. In order to reduce edge effects, researchers only sampled if the quadrat landed ½ m or more away from the edge of the quadrat. If it was not, the quadrat was re-thrown. Where it landed was sub sampled. Three subsamples were obtained per 9-m^2 quadrat during each two week period. The number of species from the subsamples and the separate 2-week periods were compiled in a simple average.

Floristic Quality Index and Statistical Analysis:

Recent studies have suggested the benefits of using the FQA that integrates the Floristic Integrity Index with other important vegetative measurements (Taft et al 1997). For each treatment, species richness was measured, and species importance values were calculated from species density, frequency, and coverage values. Species richness per treatment was calculated using mean quadrat species richness ($\bar{x}R$) and mean quadrat native species richness ($\bar{x} R_n$). For each treatment, species relative frequency (RF_i) was calculated using $f_i/\sum f_i$ x 100. Species relative abundance (RA_i) was calculated using $r\bar{a}_i$ x 100 where $r\bar{a}_i = (\bar{a}_i / \sum \bar{a}_i)$ where a_i is the averaged 3 subsamples and bimonthly sampling of stems present for each plant species. Relative Dominance (RD_i) was calculated using $\bar{c}_i/\sum \bar{c}_i$ x 100 where c_i is the percent of the quadrat covered by the above ground portion of each species and $\bar{c}_i = \sum c_i/10$ The RF_i + RA_i + RD_i was added to calculate species importance value (IV_i).

Whole treatment diversity was calculated with the Simpson's Diversity Index equaling $1/\sum \bar{r}a_i^2$. Vegetative integrity per treatment was analyzed using FQI and Mean C calculated by $\bar{x}C * \sqrt{S_n}$ where $\bar{x}C$ is the mean coefficient of conservatism across all species in the treatment. Whole treatment Species Richness was calculated with the Species Richness Index (SRI) = $\bar{x}R \cdot \ln S$ and Native Species Richness (NRI) = $\bar{x}R_n \cdot \ln S_n$. S is the total number of species per treatment, and S_n is the number of native species per treatment. Alien Index (AI) was calculated by subtracting the SRI – NRI. Species composition was compared between the SGH and SGF treatments by the Jaccard coefficient, S_j=a/(a+b+c), and Sorensen coefficient, S_s= 2a/(2a +b+c); where a is the number of species common to SGH and SGF treatments, b is the number of species in the SGH but not the SGF treatment, and c is the number of species in the SGF but not the SGH treatment.

There seems to be some disagreement in the literature for how to interpret the FQI values. According to Packard & Mutel the FQI values for a very high quality prairie per ¼ m^2 is about 20 or higher (1997), while Taft et al (1997) cite an FQI between 20-35 may be degraded but have potential for recovery. Prairies with FQI values of 35 or higher are regionally noted, and 45 or higher have statewide significance (Taft et al 1997). A replicate with species diversity greater than 20 species/per 1/4m^2 area will be considered a high quality prairie. Treatment 1 FQI value was compared to treatment 2's FQI value to determine which is more successful. The treatment with the higher FQI value would suggest this treatment is more successful and contains more native species.

A repeated measures analysis of variance (ANOVA) was used to compare the number of species between treatments, sampling years and the interaction of treatment and sampling year. The total cost of each of the three treatments was calculated and compared to their respective FQI values and additional measures of prairie quality.

The study site is a good representation of restored prairies in Will county subdivisions. It is small in size, was recently an agriculture site (within the past year), and is in close proximity to a road. The site has high quality soil, which may not be true of all prairie sites, however likely if land has recently been used for agriculture. Though prairie burns are suggested to increase propagation success of native species, the quadrats were not be burned because it was a short-term study.

It was anticipated that hand planting forbs would increase prairie quality, and be an advantageous avenue for new subdivisions in Will County restoring prairies to meet the Open Land suggested measure. Use of hand planting as a management practice came down to cost versus prairie quality. If the hand planting significantly improved prairie quality, it may be worth the initial expense and realistic for these small prairies.

RESULTS

Species composition and number in the three treatments

Upon comparison between the three treatments giant foxtail and black eyed susan were dominant in all treatments. Because both species have low C values, however, they are less desirable species in prairie restorations. The control treatment was dominated by weed species with low C values, while both SGH and SGF treatments shared many of the same species with C values of 5 and above (Table 1, Table 2, Table 3 and Table 4). The relative abundance curves for the SGH treatment, the SGF treatment and control treatment also suggest that a few species dominate in all 3 treatments (Figure 2). When considering the relative frequency, relative abundance and relative dominance the importance values can be calculated. The four most important species for the SGH treatment were giant foxtail (*Setaria faberi*) 67.0, black-eyed susan (*Rudbeckia hirta*) 63.21, purple prairie clover (*Petalostemum purpureum*) 26.86, and New England aster (*Aster novae-angliae*) 24.48. The four most important species for SGF treatment were black eyed susan (*Rudbeckia hirta*) 71.66, giant foxtail (*Seteria fabert*) 69.68, purple prairie clover (*Petalostemum purpureum*) 37.38 and wild bergamont (*Monarda fistulosa*) 15.30. The four most important species for the NSG or control quadrat were giant foxtail (*Setaria faberi*) 116.90, dandelion (*Taraxacum officinale*) 38.58, Canadian thistle (*Cirsium arvense*) 28.73, and tall goldenrod (*Solidago altissima*) 22.80. The control treatments' four species have C values of 1 and 0, while the SGH and SGF treatments' top four species have C values that range from 0-9 (Table 1, Table 2 and Table 3). The number of species (S) for the SGH treatment was 33 and the number of native species (S_n) was 28 (Table 5). When calculating the number of species (S) for the SGF treatment the one unknown was included in the 34 species; however, when calculating the number of native species (S_n) the unknown was not included to total 28 native species (Table 5). The number of species (S) for the control treatment was 21 and the number of native species (S_n) was 18 (Table 5).

Community index in the three treatments

When calculating Simpson's diversity index, SRI and NRI for the SGF treatment the unknown was included (Table 6). FQI analysis the unknown was not used for the SGF treatment (Table 6).

Species curve in the three treatments

Analysis of the species area curve for the SGH quadrats shows there were 33 species in the SGH treatment and that not all the quadrats contained the same species. The species area curve for the SGF quadrats shows there were 34 species in the SGF treatment and these quadrats had different species compositions. The control quadrats' species area curve shows the NSG treatment had 21 species and that quadrats were similar in species composition (Figure 1).

Cost comparison in the three treatments

It took 1 hour for 2 people to hand plant in 1 quadrat. Each SGH quadrat cost $19.97 for seed, $87.50 for the 35 plants and $16.50 for labor. Each SGF quadrat cost $19.97 for seed. Thus, each hand planted quadrat had a total cost of $123.97 (Table 10).

Between Quadrat Comparisons

The SGH quadrats were compared to the SGF quadrats using the Jacquard coefficient 0.76 and Sorenson Coefficient 0.87. The SGH quadrats were compared to the NSG quadrants using the Jaccard coefficient 0.51 and Soreson coefficient 0.68. The SGF quadrat and NSG quadrat were compared using the Jaccard coefficient 0.50 and Soreson coefficient 0.67 (Table 7 and 8).

ANOVA Analysis

Overall, there was a significant difference between the means for treatment ($F_{2,27}$=168.85, p<0.05), year ($F_{1,27}$=65.54, p<0.05) and the interaction of treatment and year ($F_{2,27}$=4.22, p<0.05) using the repeated measures ANOVA test criteria. Between years 2009 and 2010 the increase in the number of species is most likely due to natural prairie succession; with each year species diversity increased as more species entered the prairie community. More prairie plant species were present in 2010 than 2009 (Table 9 and Figure 3).

DISCUSSION:

Species compositions of the treatments were compared using the Jaccard coefficient and the Sorenson coefficient. Both the Jaccard coefficient, 0.76, and the Sorenson coefficient, 0.87, show that species compositions were similar between the SGH and SGF treatments. Both the Jaccard and Sorenson coefficients suggested low similarity, few shared species, between these two treatments and the control treatment (Table 7 and 8).

The species area curve suggests of the 33 species in the SGH quadrats there was a variability of species composition; not all the quadrats contained the same species composition (Figure 1). The species area curve for the SGF quadrats had 34 species total and had different species compositions in the different quadrats (Figure 3). The variability in species composition could have been due to different exposures to water or nutrients depending where the plots were on the land. The species area curve for the NSG quadrats shows the 21 species and the close similarity in the species composition in these control quadrats (Figure 5). The similarity of species composition in the NSG quadrats could be due to the dominance of weeds in these plots. The study site seemed to have a similar weed seed bank across the site, and these plants flourished regardless of nutrient or water levels. The only factor that seemed to reduce their numbers was competition with native forbs planted or seeded in the other two treatments.

All three treatments' species abundance curves suggest a few species dominate each treatment. The NSG quadrats had one dominant species, the giant foxtail. Both the SGH and SGF quadrats had three species, giant foxtail, black-eyed susan and purple prairie clover dominant. It is not uncommon for ecological communities to be dominated by only a few species, and in prairies a few species may take up to 95% of the available area (Preston 1948, 1962; Magurran 1988; Howe 1994). The SGH quadrats, however, had one additional species at a mean abundance of approximately 5, New England aster. The New England aster, with a C value of 4, is comparable to the SGF quadrats' 4th most dominant plant, wild bergamot, mean C value 4. The two treatments' most dominant species are similar in terms of C values and their importance in the prairie. The SGH quadrats had a graph with a slightly more gradual slope than the SGF quadrats. This graph shape may suggest the plants in the SGH quadrats share dominance, are more equally represented, than the plants in the SGF quadrats (Figure 2). The SGH quadrats had a better representation of species and had fewer weeds in its top ten most dominant species. These more desirable species included prairie blazing star with a mean C of 8 and pale purple coneflower with a mean C value of 8, both absent in the top ten of the seed only quadrats (Table 1 and 4). The advantage of the SGH treatment having a more even abundance among species, is high evenness can increase resistance to invasion by weeds, increase productivity above and below ground and can reduce extinction rates of native plants (Wilsey & Potvin 2000; Wilsey & Polley 2002, 2004; Smith et al 2004).

It appears the SGH quadrats have a slightly better community structure than the SGF quadrats. Both of these have better community structures than the control quadrats which are dominated by weed species. The SGH treatment had 33 species and the SGF quadrat had 34 species. Of the NSG quadrats' 21 species, eight are weeds and the non-weed species have low C values. The few purple prairie clover or prairie blazing star plants that were counted presumably blew over from neighboring quadrats. The 5 m separation between plots did greatly minimize seeds blowing from quadrat to quadrat since only a handful of prairie species were found in control quadrats. There was some transfer of black eyed susans, wild bergamonts and purple prairie clover but the transfer was at low numbers considering how these species dominated the other quadrats. There were only a few prairie blazing stars, New England asters, and purple coneflowers counted in the control quadrats.

All of the quadrats had FQI values that would suggest low quality degraded prairies with all of their FQI values below 20. The SGH treatment FQI of 8.56 was slightly higher than the SGF treatment FQI of 8.24. The NSG treatment FQI was lower at 6.14. It appears it is only at 6.14 because a few species blew over from neighboring quadrats (Table 6). Measurements of species richness are often lower in restoration sites as compared to remnant sites. It takes many years to build up a diverse seed bank, proper soil conditions with the proper bacteria, nutrients and fungi that encourage the growth of prairie forb species (Kindscher and Tieszen 1998; Polley, et al 2005).

Overall, there was a significant difference between the treatments ($F_{2,27}$=168.85, $p<0.05$), between sampling years 2009 and 2010 ($F_{1,27}$=65.54, $p<0.05$) and between the interaction of treatment and year ($F_{2,27}$=4.22, $p<0.05$). The mean number of species was greater in 2010 than in 2009 sampling years. Between years 2009 and 2010 the increase in the number of species is most likely due to natural prairie succession, with each year species diversity increased as more species enter the prairie community. More prairie plant species were present in 2010 than 2009 (Table 13 and Figure 7).

The average number of species for the SGH and the SGF treatments was larger than the mean for the NSG treatment. This result is expected since there were primarily weed species in these quadrats and no native prairie seed mixes or hand planted forbs added to these quadrats. The number of species in the control quadrats was significantly less 22 species compared to 33 and 34 species in the comparison quadrats.

The interaction of year and treatment was larger for the NSG and SGF treatments than for the SGH treatment ($F_{2, 27}=4.22$, $p<0.05$). There was presumably a larger increase in number of species in the SGF treatment than in the other two treatments from 2009 to 2010 because the seed bank had a winter to propagate the seeds. Some of the seeds begin to grow after cold, moist stratification provided by the winter weather. The SGH quadrats had hand planted plants that did not need stratification; the plants were already established by summer of 2010. These established hand planted forbs may have taken up available niches taking up water, nutrients, and space from the now stratified seed bank. This is also supported since many of the new species that arose in 2010 in the seed only treatment required cold moist stratification to propagate, including *Solidago rigida* (stiff goldenrod), *Rudbeckia subtomentosa* (sweet black eye susan), *Baptisia leucantha* (white wild indigo), *Ratibida pinnata* (yellow coneflower) and *Parthenium integrifolium* (wild quinine). Some restorationists will emulate this cold, moist weather by refrigerating the seed in moist sand but the Will County restoration organizations, including J.F. New simply sew the seed without preparing the seed. In order to make this study applicable to Will County restoration efforts, this study did not stratify the seed before it was spread.

New subdivisions, especially those in Will County, are working to incorporate natural areas into their site management plans. For example, the Lighthouse Point subdivision in Frankfort, IL has prairies, bike paths and ponds with natural vegetation managed by a collaboration of Frankfort square park district, village of Frankfort and Land Resource Management Group out of Bradley, IL. These cooperatives face challenges when residents paying upwards of $600,000 or more for their residence feel these natural areas are an "eyesore."

There was a several year battle in Orland Park, IL as the Police station attempted to "go green" and place a prairie in front of their station. Years of complaints from citizens and the village to Sollitt Management Group led to the company refunding the $10,000 and leaving the project. The community argued that after three years the prairie still looked "weedy" and was not aesthetically pleasing.

It appears the debate here is cost verse aesthetics. Many of these prairies are located in high income communities and neighborhoods. Though it is costly to hand plant forbs, the extra forb visibility in the grasses may ease complaints from residents that the prairies "look weedy." Ideally time would allow for natural succession of the prairies to lead to increased forb growth but communities who have invested $10, 000 or more get anxious to see results and climax communities.

In future research soil nitrogen tests must be used to measure the amount of nitrogen in the soil as this can limit the species present in the restoration. Though agricultural fields may never reach climax plant community due to the years of farming, degeneration of soils, nutrient leaching, and other disturbance enhancing the soil may help the site reach its maximum potential. In primary succession nitrogen is the main limiting reactant to plant growth (Chapin et al 2002). Konza Prairie Biological Station at Kansas State University has been studying best practices in prairie restorations since 1998. The field station experimental results have shown the important of nutrient availability and soil chemistry has a strong impact on the success of prairie restorations and obtaining high plant species diversity. Early on it was found that be reducing the nitrogen available in the soil, reduced the number of non-native species and increased plant diversity. However the cost to change soil chemistry and reduce the nitrogen-nitrate levels, especially in converted agricultural fields is beyond the scope of most prairie restoration budgets (Baer et al. *Ecology* 2003; Baer et al. *Oecologia* 2004; Konza Prairie Biological Station 2010; L. Heneghan et al. 2008). Conversion of prairie to row crops increases homogeneity of the soil by repeatedly mixing and leveling the soil, and planting the same crops year after year. There is also the addition of high levels of nitrogen to the soil through yearly fertilization of the soil. For successful prairie restorations with high species diversity, soils need to be heterogenous and have reduced nitrogen levels (Rover & Kaiser 1997; Baer et al. *Restoration Ecology* 2005; Steinauer & Collins 1995).

It is predicted that the hand planted plots will have reduced nitrogen-nitrate soil readings causing reduced nitrogen availability, reduced weedy species and increased native prairie species in these plots.

LITERATURE CITED:

Anderson, , R.C. 1990. The historic role of fire in the North American gassland. Pages 8-8 in S. L. Collins and L. L. Wallace, editors. Fire in North American tallgrass rairies. University of Oklahoma Press, Norman.

Baer, S. G., J. M. Blair, S. L. Collins, and A. K. Knapp. 2003. Soil resources regulate productivity and diversity in newly established tallgrass prairie. *Ecology*, **84,** 724–735.

Baer, S. G., J. M. Blair, S. L. Collins, and A. K. Knapp. 2004. Plant community responses to resource availability and heterogeneity during restoration. *Oecologia* **139**, 617–639.

Betz, R. 1986. One decade of research in prairie restoration at the Fermi National Accelerator Laboratory (Fermilab), Batavia, Illinois. Pages179-185 in G. K.

Clamby and R. H. Pemble, editors. The prairie-past, present, and future, Proceedings of the Ninth North American Prairie Conference, Fargo, North Dakota, 29 July to 1 August, 1984. Tri-College University Center for Environmental Sciences, North Dakota State University, Fargo.

Bowles, M. & Jones M. (2006). Testing the efficacy of species richness and floristic quality assessment of quality, temporal change, and fire effects in tallgrass prairie natural areas. *Natural Areas Journal*, **26**, 17-30.

Chapin, F., P. Matson, and H. Mooney. 2002. Principles of terrestrial ecosystem ecology. Springer-Verlag, New York, New York.

Collins, S.L. & Wallace, L.L. (1990). *Fire in North American Tallgrass Prairies,* pp. - . University of Oklahoma Press, London.

Copeland, T. E., W. Sluis, and H.F. Howe. 2002. Fire season and dominance in an Illinois tallgrass prairie restoration. *Restoration Ecology*, **10** (2), 315-323.

Cottam, G. & Wilson, H. C. 1966. Community dynamics on an artificial prairie. *Ecology*, **47**, 88-96.

Fitch, H. S. & Hall, E.R. 1978. A 20 – year record of succession on reseeded fields of tallgrass praririe on the Rockefeller experimental tract. Special publication 4. Museum of Natural History, University of Kansas, Lawrence, Kansas.

Fuhlendorf, S.D. and D. M. Engle. 2004. Application of the fire-grazing interaction to restore a shifting mosaic on tallgrass prairie. *Journal of Applied Ecology*, **41**, 604-614.

Heneghan, L., S. P. Miller, S. Baer, M. Callaham, Jr., J. Montgomery, M. Pavao-Zuckerman, C. Rhoades, & S. Richardson. 2008. Integrating soil ecological knowledge into restoration management. *Restoration Ecology,* **16**, 608–617.

Howe, H.F. 1994. Managing species diversity in tallgrass prairie: assumptions and implications. Conservation Biology **8**: 691-704.

Kettle, D. W., P. Rich, K. Kindscher, G.L. Pittman and P. Fu. 2000. Land-use history in ecosystem restoration: a 40-year study in the prairie-forest ecotone. *Restoration Ecology*, **8** (3), 307-317.

Kindscher, K. & Tieszen, L. L. (1998). Floristic and soil organic matter changes after five and thirty-five years of native tallgrass prairie restoration. *Restoration Ecology*, **6**, 181-196.

Konza Prairie Biological Station. 2010. http://kpbs.konza.ksu.edu/research_focus.html. Kansas State University. Manhattan, Kansas.

Kuchler, A.W. 1964. Potential natural vegetation of the continuous United States. merican Society of Geography, Special Publication **36**.

Magurran, A. E. 1988. Ecological diversityand its measurement. Princeton University Press, Jersey. Princeton, New Jersey.

Packard, S. & Mutel, C.F. (1997). *The Tallgrass Restoration Handbook for prairies, savannas, and woodlands*, pp. 67-68. Island Press, Washington, D.C.

Page, L.M., M. Pyron and K.S. Cummings. 1997. Impacts of fragmentation on Midwestern organisms. In: *Conservation in Highly Fragmented Landscapes.* M. W. Schwartz, ed. p. 182-212.

Piper, J.K. and S. L. Pimm. 2002. The creation of diverse prairie-like communities. *Community Ecology*, **3**, 205-216.

Polley, H.W, Derner, J.D. & Wilsey, B.J. 2005. Patterns of plant species diversity in remnant and restored tallgrass prairies. *Restoration Ecology,***13** (3), 430-487.

Preston, F. 1948. The commonness and rarity of species. *Ecology*. **29**: 254-283.

Preston, F. 1962. The canonical distribution of commonness and rarity. Part I. *Ecology.* **43**, 185-215.

Pywell, R. F., Bullock, J.M., Roy, D.B., Warman, L., Walker, K.J. & Rothery, P. 2003. Plant traits as predictors of performance in ecological restoration. *Journal of Applied Ecology,* **40**, 65-77.

Saunders, D.A. 1991. Biological consequences of ecosystem fragmentation: a review. *Conservation Biology* **5**, 18-32.

Shirley, S. 1994. Restoring the tallgrass prairie. University of Iowa Press, Iowa City, Iowa.

Sluis, W. J. (2002). Patterns of species richness and composition in re-created grassland. *Restoration Ecology*, **10**, 677-684.

Smith, R.S., Shiel, R.S., Bardgett, R.D., Millward, D., Corkhill, P., Rolph, G., Hobbs, P.J. & Peacock, S. 2003. Soil microbial community, fertility, vegetation and diversity as targets in the restoration management of a meadow grassland. *Journal of Applied Ecology*, **40**, 51-64.

Smith, M. D., J. C. Wilcox, T. Kelly & A.K. Knapp. 2004. Dominance not richness determines invisibility of tallgrass prairie. *Oikos*, **106**, 253-262.

Taft, J.B., Hauser, C. & Robertson, K.R. (2006). Estimating floristic integrity in tallgrass prairie. *Biological Conservation,* **131**, 42-51.

Taft. J.B., Wilhelm, G.S., Ladd, D.M. & Masters, L.A. (1997). Floristic quality assessment for vegetation in Illinois a method for assessing vegetation integrity. Erigenia **15**: 3-23.

Temperton, V.M., Hobbs, R.J., Nuttle, T. & Halle, S. (2004). *Assembly Rules and Restoration Ecology Bridging the Gap between Theory and Practice*, pp. - . Island Press, Washington.

Whitney, G. C. 1994. From coastal wilderness to fruited plain. Cambridge University Press, New York.

Wilsey, B. J. & H. W. Polley. 2002. Reductions in species evenness increase dicot seedling invasion and spittle bug infestation. *Ecology Letters*, **5**, 676-684.

Wilsey, B.J. & H.W. Polley. 2004. Realistically low species eveness does not alter grassland-species richness-productivity relationships. *Ecology*, **85**, 2693-2701.

Wilsey, B.J. & C. Potvin. 2000. biodiversity and ecosystem functioning: importance of species eveness in an old field *Ecology,* **81**, 887-892.

Table 1. The importance value, relative frequency, relative abundance, relative dominance and coefficient of conservatism of plant species in SGH quadrats.

Common Name	Species Name	Importance Value	Relative Frequency	Relative Abundance	Relative Dominance	C
giant foxtail	*Setaria faberi*	67.00	5.35	40.80	20.86	
black eyed susan	*Rudbeckia hirta*	63.21	5.35	28.65	29.21	1
purple prairie clover	*Petalostemum purpureum (Dalea purpurea)*	26.86	5.35	12.33	9.17	9
New England aster	*Aster novae-angliae*	24.48	5.35	4.88	14.25	4
purple coneflower	*Echinacea purpurea*	16.38	5.35	3.38	7.66	3
wild bergamont	*Monarda fistulosa*	10.06	5.35	1.97	2.75	4
prairie blazing star	*Liatris pycnostachya*	9.68	5.35	0.98	3.36	8
sweet black eyed susan	*Rudbeckia subtomentosa*	8.93	5.35	1.21	2.38	9
pale purple coneflower	*Echinacea pallida*	8.76	5.35	0.83	2.57	8
pokeweed	*Phytolacca americana*	8.57	5.35	1.46	1.76	1
tall amaranthus	*Amaranthus powellii*	7.55	4.81	1.42	1.31	
Canadian wild rye	*Elymus canadensis*	5.52	4.28	0.66	0.59	4
dandelion	*Taraxacum officinale*	4.41	3.74	0.14	0.53	
Canada thistle	*Cirsium arvense*	4.26	2.68	0.39	1.20	
honey locust	*Gleditsia triacanthos*	3.93	3.74	0.05	0.13	2
tall goldenrod	*Solidago altissima*	3.74	3.21	0.10	0.42	1
horseweed	*Erigeron canadensis*	3.60	3.21	0.09	0.31	0
yellow coneflower	*Ratibida pinnata*	2.36	2.14	0.16	0.07	4
prairie dock	*Silphium terebinthinaceum*	2.28	2.134	0.03	0.11	5
black nightshade	*Solanum americanum*	1.89	1.60	0.03	0.25	0
White wild indigo	*Baptisia leucantha*	1.77	1.60	0.03	0.13	8
hairy aster	*Aster pilosus*	1.75	1.60	0.03	0.11	0
Daisy fleabane	*Erigeron annuus*	1.74	1.60	0.02	0.11	5
compass plant	*Silphium laciniatum*	1.66	1.60	0.02	0.04	5
biennial gaura	*Gaura biennis*	1.33	1.07	0.04	0.22	2
Stiff goldenrod	*Solidago rigida*	1.31	1.07	0.11	0.13	4
Queen Ann's lace	*Daucus carota*	1.27	1.07	0.08	0.12	
Canadian milk vetch	*Astragalus canadensis*	1.17	1.07	0.02	0.09	10
eastern cottonwood	*Populus deltoides*	1.17	1.07	0.04	0.05	2
brown eyed susan	*Rudbeckia triloba*	1.12	1.07	0.02	0.03	3
white clover	*Trifolium repens*	1.11	1.07	0.01	0.03	
mugwort	*Artemisia vulgaris*	0.57	0.53	0.01	0.02	
switch grass	*Panicum virgatum*	0.54	0.53	0.01	0.01	5

Table 2. The importance value, relative frequency, relative abundance, relative dominance and coefficient of conservatism of plant species in SGF quadrats.

Common Name	Species Name	Importance Value	Relative Frequency	Relative Abundance	Relative Dominance	C
black eyed susan	*Rudbeckia hirta*	71.66	5.75	30.08	35.83	1
giant foxtail	*Setaria faberi*	69.68	5.75	41.17	22.77	
purple prairie clover	*Petalostemum purpureum (Dalea purpurea)*	37.38	5.75	17.04	14.6	9
wild bergamont	*Monarda fistulosa*	15.30	5.75	3.59	5.96	4
purple coneflower	*Echinacea purpurea*	12.01	5.75	2.17	4.09	3
New England aster	*Aster novae-angliae*	9.74	5.75	1.07	2.92	4
sweet black eyed susan	*Rudbeckia subtomentosa*	9.71	5.75	1.37	2.59	9
pokeweed	*Phytolacca americana*	9.02	5.75	1.21	2.059	1
dandelion	*Taraxacum officinale*	6.32	4.02	0.45	1.84	
tall amaranthus	*Amaranthus powellii*	6.18	5.17	0.17	0.84	
Canadian wild rye	*Elymus canadensis*	5.75	4.60	0.54	0.62	4
horseweed	*Erigeron canadensis*	4.99	4.60	0.08	0.31	0
pale purple coneflower	*Echinacea pallida*	4.99	4.60	0.09	0.30	8
tall goldenrod	*Solidago altissima (Solidago canadensis scabra)*	4.08	3.45	0.10	0.53	1
prairie dock	*Silphium terebinthinaceum*	3.87	1.72	0.02	2.13	5
Canadian Thistle	*Cirsium arvense*	3.25	2.30	0.15	0.80	
stiff goldenrod	*Solidago rigida*	2.70	2.30	0.20	0.21	4
White wild indigo	*Baptisia leucantha*	2.56	2.30	0.04	0.22	8
White clover	*Trifolium repens*	2.43	2.30	0.06	0.08	
honey locust tree	*Gleditsia triacanthos*	1.94	1.72	0.03	0.18	2
Hairy aster	*Aster pilosus*	1.92	1.72	0.02	0.17	0
daisy fleabane	*Erigeron annuus*	1.88	1.72	0.03	0.13	5
Yellow coneflower	*Ratibida pinnata*	1.863115	1.72	0.02	0.11	4
early (false) sunflower	*Heliopsis helianthoides*	1.82	1.72	0.02	0.08	5
biennial gaura	*Gaura biennis*	1.47	1.15	0.05	0.28	2
black nightshade	*Solanum americanum*	1.24	1.15	0.02	0.07	0
eastern cottonwood tree	*Populus deltoides*	1.23	1.15	0.03	0.04	2
velvet leaf	*Abutilon theophrasti*	1.20	1.15	0.02	0.03	
Kentucky bluegrass	*Poa pratensis*	0.72	0.57	0.10	0.45847	

Queen Ann's lace	*Daucus carota*	0.65	0.57	0.02	0.05	
Canadian milk vetch	*Astragalus canadensis*	0.63	0.57	0.01	0.05	10
compass plant	*Silphium laciniatum*	0.60	0.57	0.01	0.02	5
unknown		0.60	0.57	0.01	0.02	
wild quinine	*Parthenium integrifolium*	0.60	0.57	0.01	0.02	8

Table 3. The importance value, relative frequency, relative abundance, relative dominance and coefficient of conservatism of plant species in NSG quadrats.

Common Name	Species Name	Importance Value	Relative Frequency	Relative Abundance	Relative Dominance	C
giant foxtail	*Setaria faberi*	116.90	8.82	67.1	40.98	
dandelion	*Taraxacum officinale*	38.56	9.80	7.49	21.28	
Canadian thistle	*Cirsium arvense*	28.73	9.80	8.08	10.85	
tall goldenrod	*Solidago altissima*	22.80	8.82	6.06	7.92	1
horseweed	*Erigeron canadensis*	17.72	6.86	4.34	6.52	0
daisy fleabane	*Erigeron annuus*	9.75	5.88	1.40	2.4	5
pokeweed	*Phytolacca americana*	8.23	6.86	0.43	0.94	1
black nightshade	*Solanum americanum*	7.60	3.92	0.67	3.01	0
stiff goldenrod	*Solidago rigida*	7.27	5.88	0.34	1.05	4
black eyed susan	*Rudbeckia hirta*	6.98	3.92	1.25	1.81	1
eastern cottonwood	*Populus deltoides*	6.14	4.90	0.30	0.94	2
Kentucky bluegrass	*Poa pratensis*	5.79	3.92	1.38	0.48	
horseweed	*Erigeron canadensis*	5.26	3.92	0.51	0.82	0
tall amaranthus	*Amaranthus powellii*	5.20	4.90	0.11	0.19	
wild bergamont	*Monarda fistulosa*	3.25962826	2.94	0.13	0.18	4
purple prairie clover	*Petalostemum purpureum*	2.35	1.96	0.26	0.13	9
honey locust	*Gleditsia triacanthos*	2.06	1.96	0.03	0.08	2
clammy ground cherry	*Physalis heterophylla*	2.03	1.96	0.03	0.04	3
prairie blazing star	*Liatris pycnostachya*	1.21	0.98	0.04	0.19	8
New England aster	*Aster novae-angliae*	1.07	0.98	0.01	0.08	4
purple coneflower	*Echinacea purpurea*	1.06	0.98	0.04	0.04	3

Table 4. Importance values and coefficients of conservatism of the top plant species dominant in the three treatments.

Common Name	Species Name	Importance Value for hand planted and seeded quadrats	Importance Value for seeded quadrats	Importance Value for control (non-seeded/planted)	C
giant foxtail	*Setaria faberi*	67.00	69.68	116.90	
black eyed susan	*Rudbeckia hirta*	63.21	71.66	6.98	1
purple prairie clover	*Petalostemum purpureum*	26.86	37.38		9
New England aster	*Aster novae-angliae*	24.48	9.73		4
purple coneflower	*Echinacea purpurea*	16.38	12.01		3
wild bergamont	*Monarda fistulosa*	10.06	15.30		4
prairie blazing star	*Liatris pycnostachya*	9.68			8
sweet black eyed susan	*Rudbeckia subtomentosa*	8.93	9.71		9
pale purple coneflower	*Echinacea pallida*	8.76			8
pokeweed	*Phytolacca americana*	8.57	9.02	8.23	1
dandelion	*Taraxacum officinale*		6.32	38.58	
tall amaranthus	*Amaranthus powellii*		6.18		
Canadian wild rye	*Elymus canadensis*				
Canadian thistle	*Cirsium arvense*			28.73	
tall goldenrod	*Solidago altissima*			22.80	1
horseweed	*Erigeron canadensis*			17.72	0
daisy fleabane	*Erigeron annuus*			9.75	5
black nightshade	*Solanum americanum*			7.60	0
stiff goldenrod	*Solidago rigida*			7.27	4

Table 5. Number of Species (S), number of native species (Sn) and mean C value ($\bar{x}C$) for plant species in three treatments.

	SGH	**SGF**	**NSG**
S	33	34	21
Sn	28	28	18
$\bar{x}C$	1.62	1.56	1.45

*** SGH:** seeding with grasses and hand planting forbs; SGF: seeding with grasses and forbs; NSG: neither seeding nor hand planting grasses or forbs.

Table 6. Simpson's Diversity Index, Floristic Quality Index (FQI), Species Richness Index (SRI) and Native Richness Index (NRI) of the three treatments.

	SGH	**SGF**	**NSG**
Simpson's	3.73	3.43	2.13
FQI	8.56	8.24	6.15
SRI	11.54	11.99	6.40
NRI	9.33	9.33	5.20
AI	2.21	2.66	1.19

* **SGH:** seeding with grasses and hand planting forbs; SGF: seeding with grasses and forbs; NSG: neither seeding nor hand planting grasses or forbs.

Table 7. Jaccard coefficent comparisons between the three treatments.

	SGF	**NSG**
SGH	0.76	0.51
SGF		0.50

* **SGH:** seeding with grasses and hand planting forbs; SGF: seeding with grasses and forbs; NSG: neither seeding nor hand planting grasses or forbs.

Table 8. Soreson coefficient comparisons between the three treatments.

	SGF	**NSG**
SGH	0.87	0.68
SGF		0.67

* **SGH:** seeding with grasses and hand planting forbs; SGF: seeding with grasses and forbs; NSG: neither seeding nor hand planting grasses or forbs.

Table 9. Repeated Measures ANOVA for average number of species verses treatment, year and plot.

Source	DF	Seq SS	Adj SS	Adj MS	F	P
Treatment	2	224.5152	224.5152	112.2576	168.85	0.000
Plot(Treatment)	27	17.9506	17.9506	0.6648	1.03	0.000
Year	1	42.4107	42.4107	42.4107	65.54	0.000
Treatment*Year	2	5.4634	5.4634	2.7317	4.22	0.025
Year*Plot(Treatment)	27	17.4716	17.4716	0.6471		
Error	0					
Total	59	307.8115				

Table 10. Cost Comparison in the three treatments.

	SGH	SGF	NSG
Cost per Quadrat	$123.97	$19.97	$0

* **SGH:** seeding with grasses and hand planting forbs; SGF: seeding with grasses and forbs; NSG: neither seeding nor hand planting grasses or forbs.

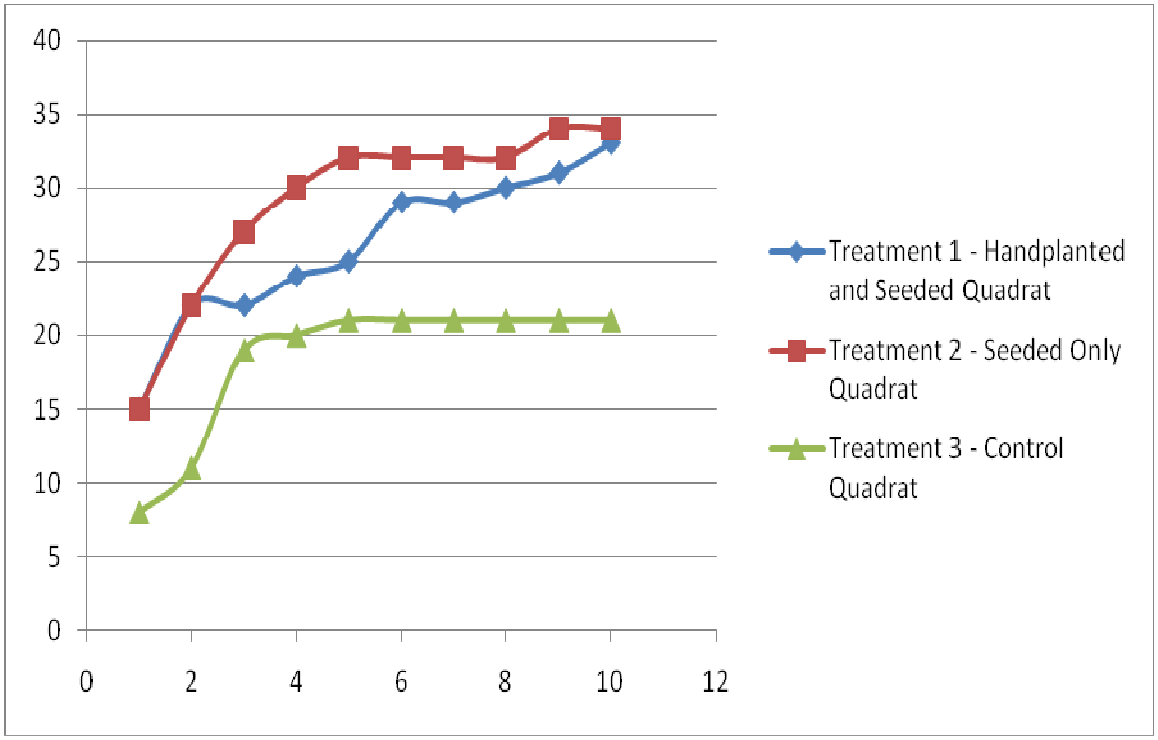

Figure 1. Species Area Curve for all three treatments.

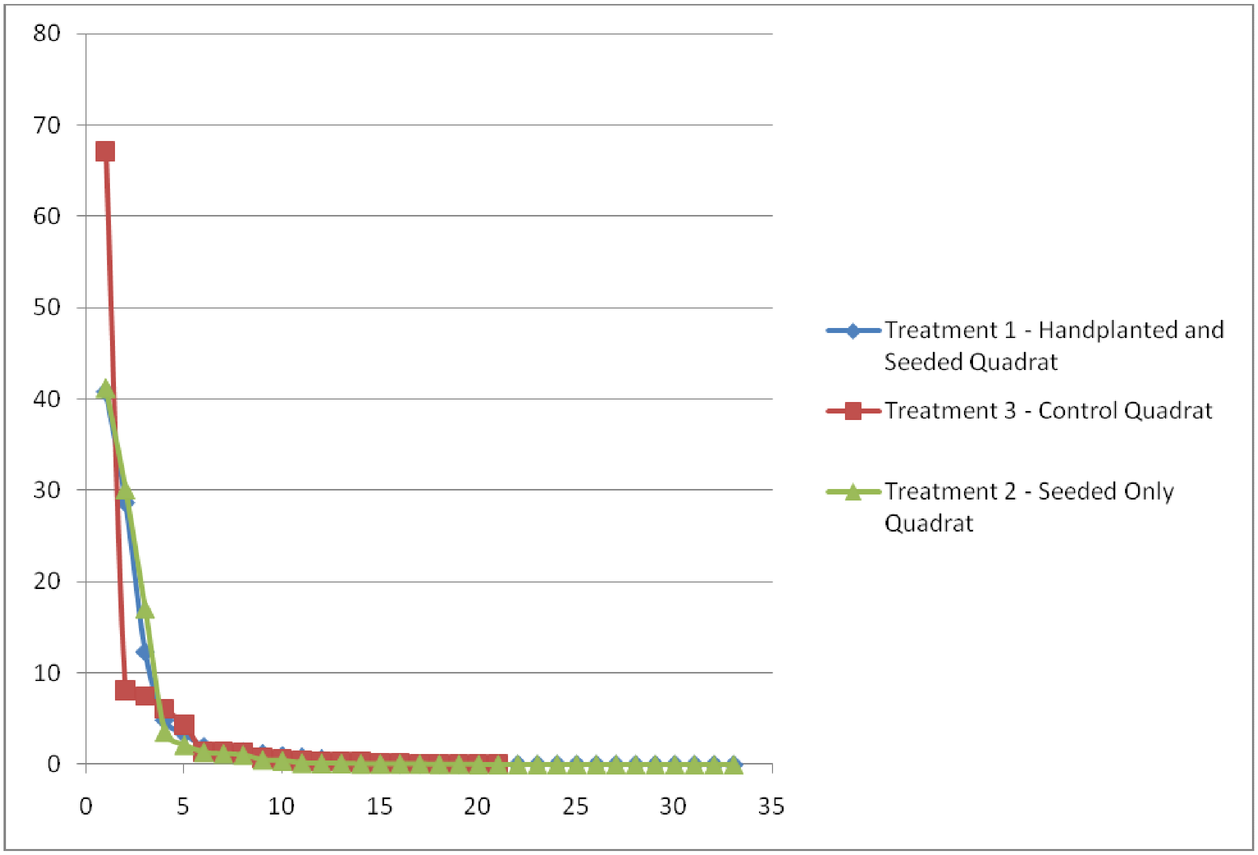

Figure 2. Species Abundance Curve for seeded and hand planted quadrats.

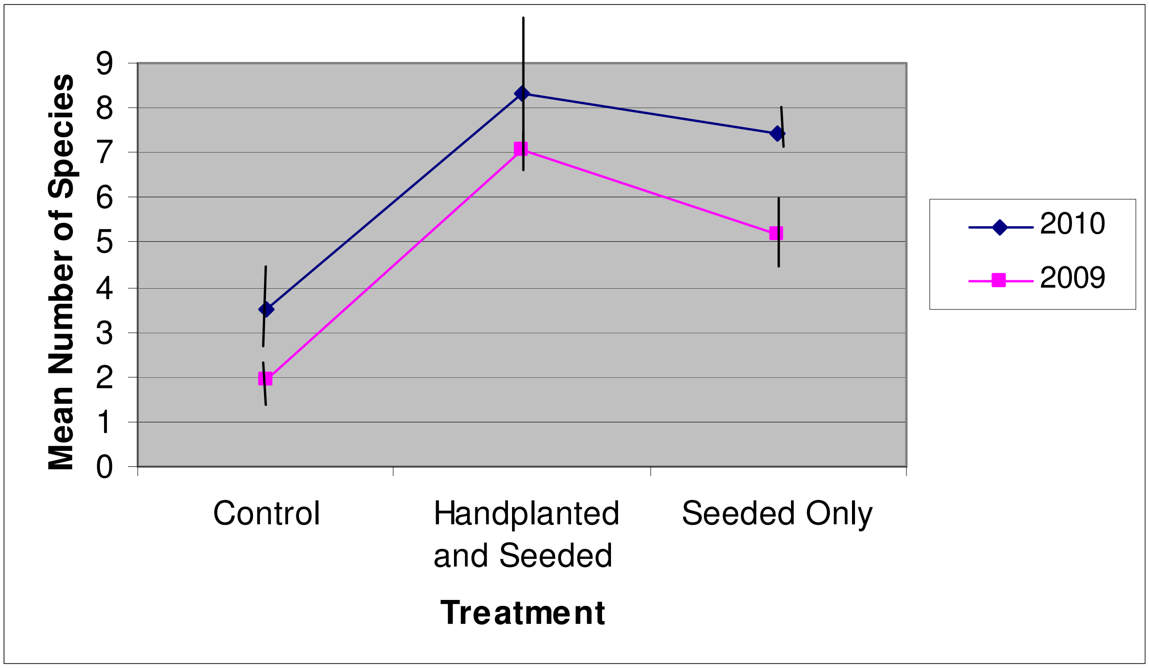

Figure 3. Interaction of 3 treatments and years 2009 and 2010.